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Quality of life after adenotonsillectomy for children with sleep-disordered breathing: A linear mixed model analysis☆

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Objective: To study changes in quality of life (QoL) after adenotonsillectomy (T&A) in children with sleep-disordered breathing (SDB), and to elucidate discrepancies in QoL improvements after T&A in children of different gender, age, adiposity status, and disease severity.

Materials and methods: Children aged 2–18 years were recruited. All children had SDB-related symptoms and underwent preoperative full-night polysomnography (PSG). Caregivers completed the first obstructive sleep apnea 18-items questionnaire (OSA-18) prior to T&A and the second OSA-18 survey within 3 months after surgery. Disease severity was defined as primary snoring (apnea/hypopnea index, AHI < 1), mild obstructive sleep apnea (OSA) ($5 > \text{AHI} \geq 1$), and moderate-to-severe OSA (AHI ≥ 5). Discrepancies in OSA-18 score changes after T&A for different groups were assessed using the linear mixed model.

Results: In total, 144 children were enrolled (mean age, 7.0 ± 3.6 years; 76% boy). The OSA-18 total score changes after surgery were not significantly different by gender (boys *vs.* girls), age group ($\geq$6 years *vs.* $<$6 years), or adiposity (obese *vs.* non-obese). The OSA-18 total score changes after surgery differed by disease severity (primary snoring *vs.* moderate-to-severe OSA, $P = 0.004$; mild OSA *vs.* moderate-to-severe OSA, $P = 0.003$). Children with moderate-to-severe OSA had greater improvement in OSA-18 total score after surgery than those with mild OSA or primary snoring.

Conclusions: Children with SDB had QoL improvement after T&A, as documented by OSA-18 score changes. The QoL improvement after T&A for SDB children increased as disease severity increased, and the improvement was not affected by gender, age, or adiposity.

1. Introduction

Sleep-disordered breathing (SDB) includes a spectrum of upper airway disorders ranging from primary snoring to obstructive sleep apnea (OSA) [1,2]. The prevalence of habitual snoring in children is 9–10%, while that of OSA is 1–3% [3,4]. Notably, SDB in children is due primary to enlarged tonsils and adenoids that obstruct the upper airway [1,2,5]. Removing tonsils and adenoids (adenotonsillectomy, T&A) is considered worldwide the first-line therapy for pediatric SDB [6–10].

Full night polysomnography (PSG) is the gold standard for diagnosing SDB in children [2]. Mounting evidence shows that PSG parameters improved dramatically after T&A [6–10]. Furthermore, for children with SDB, T&A improved outcomes in sleep studies, and positively influenced quality of life (QoL) [11,12]. Among available QoL instruments, the obstructive sleep apnea 18-items quality of life questionnaire (OSA-18) is a widely used disease-specific QoL survey for pediatric obstructive sleep disorders [13]. According to literature, children had significant short-term and

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long-term QoL improvements after T&A, as documented by changes in OSA-18 scores [12,14–16]. However, factors affecting QoL changes after T&A for children with SDB, have not been verified.

This study elucidates changes in QoL for children with SDB underwent T&A. In particular, this study investigates discrepancies in QoL changes after T&A for children of different gender, age, adiposity status and disease severity.

2. Materials and methods

2.1. Study population

The study protocol and informed consent for OSA-18 questionnaires were approved by the Ethics Committee of the National Taiwan University Hospital. From July 2010 to December 2012, children aged 2–18 years were recruited. Children were enrolled when they had signs and symptoms of a sleep disturbance including snoring, mouth breathing, and witnessed breath holding by caregivers for at least 1 month duration [17]. Adenoid size was determined using a lateral cephalometric radiograph. The adenoidal–nasopharyngeal (AN) ratio was measured on the lateral radiograph as the ratio of adenoidal depth to nasopharyngeal diameter according to the method by Fujioka et al. [18]. Tonsils were graded using the scheme by Brodsky et al. [19]: grade I, small tonsils confined to the tonsillar pillars; grade II, tonsils extending just outside the pillars; grade III, tonsils extending outside the pillars, but do not meet at the midline; grade IV, large tonsils that meet at the midline. Children with an AN ratio $\geq$0.5 or tonsil grade $\geq$2 underwent T&A as definite treatment. Exclusion criteria were (1) prior tonsil, adenoid, or pharyngeal surgery; (2) cranio-facial anomalies; (3) genetic disorders, neuro-muscular diseases, or mental retardation.

Basic data, clinical history, physical examination data were obtained. The weight and height of each child were measured, and the age- and gender-corrected body mass index (BMI) was applied for each child using established guidelines [20]. Obesity was defined as a BMI higher than the 95th percentile for a child's age and gender [5,9,20,21]. All subjects underwent a preoperative PSG study to define SDB severity [22]. The QoL assessment tool is based on the OSA-18 questionnaire, which is an 18-item questionnaire completed by the subject's caregiver [13,23].

2.2. Polysomnography (PSG)

All subjects completed an overnight PSG study before and after surgery. The overnight PSG (Embla N7000, Medcare Flaga, Reykjavik, Iceland) was performed in the sleep lab following a protocol described elsewhere [5,9,19,23,24]. The sleep stage and respiratory events were scored based on the 2007 American Academy of Sleep Medicine standard [22]. Obstructive apnea was defined as the presence of continued inspiratory effort associated with a >90% decrease in airflow for duration of $\geq$2 breaths. Hypopnea was defined as a $\geq$50% decrease in airflow for duration of $\geq$2 breaths that was associated with arousal, awakening, or reduced arterial oxygen saturation of $\geq$3%. Disease severity was defined as primary snoring (apnea/hypopnea index, AHI <1), mild obstructive sleep apnea (OSA) ($5 > \text{AHI} \geq 1$), and moderate-to-severe OSA ($\text{AHI} \geq 5$) [6–9].

2.3. OSA-18 QoL questionnaire (OSA-18)

All subjects completed the validated OSA-18 questionnaires before and after surgery. Franco et al. [13] first designed the OSA-18, and Kang et al. [23] translated and validated the traditional Chinese version. As a caregiver-administered QoL survey, the OSA-18 contains 18 items divided into five subscales: sleep disturbance; physical symptoms; emotional distress; daytime function; and caregiver concerns. Each is scored on a 7 point ordinal scale. The OSA-18 is graded to produce a score for each item, additional scores for the 5 sub-scales, and a total score. The OSA-18 total score is the sum of scores for the 18 items and, therefore, ranged from 18 (no impact on QoL) to 126 (major negative impact) [13,23].

2.4. Adenotonsillectomy (T&A)

Tonsillectomy was performed using the coblation method, and adenoidectomy was performed using the microdebrider-assisted method. All surgical procedures were performed in a single stage under general anesthesia, followed by hospitalization for two days [9,25].

2.5. Statistical analysis

Data were analyzed using SPSS Statistics 20.0 (IBM Corporation, New York, United States). Continuous data were expressed as the mean and standard deviation, and categorical data as the number and percentage. Continuous data before and after surgery were compared using the paired-sample *t*-test. The standard response mean (SRM), defined as the difference score divided by its standard deviation, was applied to estimate the strength of improvement in OSA-18 scores. The SRM of effect size increased with improvements in life quality among children who underwent T&A [26].

The main objective of this study is to explore whether the improvement of QoL before and after T&A differs between different subgroups. The use of linear mixed models (LMM) for analyzing repeated-measure data results in a more precise parameter estimation than that in traditional statistical methods (*e.g.*, linear regression) [27–30]. The equation of LMM consists of two levels.

Equation in level 1

$$Y_{ij} = \pi_{0i} + \pi_{1i}\text{TIME}_{ij} + e_{ij}$$

Equation in level 2

$$\pi_{0i} = \beta_{00} + \beta_{01}\text{Gender} + \beta_{02}\text{Age} + \beta_{03}\text{Adiposity} + \beta_{04}\text{Severity} + r_{0i}$$

$$\pi_{1i} = \beta_{10} + \beta_{11}\text{Gender} + \beta_{12}\text{Age} + \beta_{13}\text{Adiposity} + \beta_{14}\text{Severity} + r_{1i}$$

Note: Y_{ij} denotes individual *i*s OSA-18 score at time *j* where *j* = 0 or 1 represents pre-surgery and post-surgery, respectively.

In level 1, only time-varying covariate (TIME) is included and it indicates each individual's growth trajectory of outcome measure (π_{1i}) by releasing its random effect in level 2 (r_{1i}). On the other hand, each individual's response at baseline (π_{0i}) is allowed to differ by releasing its random effect in level 2 (r_{0i}). In level 2, the regression coefficients (β_{01}–β_{04}) represents that each participants' initial status (intercept) will be associated with their covariates. Importantly, the regression coefficients (β_{11}–β_{14}) indicates the interaction terms of time by the covariates which represents that the impact of time (π_{1i}) on outcome will be associated with their covariates. That is, the changes in OSA-18 score (time effect) are significantly different for a given subgroup when a significant interaction term appears.

As listed in the above equations, we adjusted for fixed effects for time, gender, age, adiposity, disease severity, and two-way interaction terms of time by each covariate as well as random effects for the intercept (baseline score) and time effect (linear slope). The random effect for the intercept was estimated, indicating that the baseline score changed across subjects. The

Table 1
The OSA-18 total scores before and after surgery.

	N	Pre-surgery	Post-surgery	SRM
All subjects	144	71.1 ± 15.7	41.2 ± 12.5	2.1
Gender				
Male	109	71.6 ± 15.3	41.0 ± 11.6	2.1
Female	35	69.3 ± 17.0	41.7 ± 15.2	1.8
Age				
<6 years	64	72.3 ± 15.7	42.5 ± 11.3	2.2
≥6 years	80	70.1 ± 15.7	40.1 ± 13.4	2.0
Adiposity				
Non-obese	117	69.9 ± 15.5	40.5 ± 12.6	2.0
Obese	27	75.9 ± 16.4	44.4 ± 12.2	2.4
SDB groups				
AHI < 1	16	66.1 ± 14.9	42.7 ± 15.3	1.6
1 ≤ AHI < 5	50	68.7 ± 14.3	42.7 ± 12.8	1.9
AHI ≥ 5	78	73.6 ± 16.4	39.9 ± 11.8	2.4

Note: Data are expressed as mean ± standard deviation; AHI = apnea/hypopnea index; OSA-18 = Obstructive sleep apnea 18-items questionnaire; SDB = sleep-disordered breathing; SRM = standardized response mean, indicating difference score divided by the standard deviation of the difference score. All *P* values from paired-sample *t*-test < 0.05.

random effect for the time effect was also estimated, indicating that each subject has his/her own growth trajectory. In terms of the random-effects covariance–variance matrix, we assumed an unstructured covariance with no specific form. In contrast to the traditional statistical methods, LMM thus allows that the baseline score and the time effect to change across subjects. A *P*-value <0.05 was statistically significant.

3. Results

3.1. Study population

Data for 144 children were analyzed. Mean age was 7.0 ± 3.6 years; 75.7% (109/144) were male. Sixty-four subjects (44.4%) were younger than 6, and 80 subjects (55.6%) were older than 6 years. Twenty-seven subjects (18.8%) were obese, and 117 (81.2%) were not obese. Mean AHI for all subjects was 13.3 ± 19.9 events/h before surgery. For all groups, 11.1% (16/144) had primary snoring (AHI < 1), 34.7% (50/144) had mild OSA (5 > AHI ≥ 1), and 54.2% (78/144) had moderate-to-severe OSA (AHI ≥ 5).

3.2. OSA-18 before vs. after surgery

Table 1 lists the OSA-18 total scores before and after surgery for all subjects. The OSA-total scores improved significantly after surgery (71.1 ± 15.7–41.2 ± 12.5, *P* < 0.001). Mean difference in total score was 29.9 with an SRM of 2.1. Among all five subscales in the OSA-18 survey, the greatest improvement was achieved in sleep disturbance (SRM, 2.0), followed by physical symptoms (SRM, 1.7), whereas the smallest improvement was in emotional distress (SRM, 0.5) (Table 2).

3.3. OSA-18 before vs. after surgery for subgroups

After surgery, the OSA-18 total scores and subscale scores improved significantly for all subgroups-gender, age, adiposity, and SDB groups (Tables 1 and 2). Mean difference in OSA-18 total scores after surgery was 30.6 (SRM, 2.1) for males and 27.6 (SRM, 1.8) for females. The sleep disturbance scale had the largest mean difference, and the emotional distress subscale had the smallest mean difference in both genders (Table 2). Mean differences in OSA-18 total scores was 29.8 (SRM, 2.2) for subjects <6, and 30.0 (SRM, 2.0) for subjects aged ≥6. The sleep disturbance scale had largest mean difference, and the emotional distress subscale had the smallest mean difference for the two age groups (Table 2). The mean differences in OSA-18 total scores for non-obese children was 29.4 (SRM, 2.0), and that for obese children was 31.5 (SRM, 2.4). Obese children had the largest improvement in the physical symptoms subscale (SRM, 2.7), whereas non-obese subjects had the largest improvement in the sleep disturbance subscale (SRM, 2.0). Nevertheless, the emotional distress subscale was the least improved domain for both obese and non-obese subjects (Table 2).

For the SDB groups, the improvement in OSA-18 total score after surgery increased as disease severity increased. The mean differences in OSA-18 total scores after surgery was 23.4 (SRM, 1.6) for children with primary snoring, 26 (SRM, 1.9) for children with mild OSA, and 33.7 (SRM, 2.4) for children with moderate-to-severe OSA (Table 1). In particular, the sleep disturbance subscale scores improved as disease severity increased. The changes in OSA-18 sleep disturbance scores was 6.9 (SRM, 1.5) for children with primary snoring, 9.7 (SRM, 2.0) for children with mild OSA, and 11.8 (SRM, 2.3) for children with moderate-to-severe OSA (Table 2). Further, the domain with the largest change for subjects with primary snoring was the physical symptoms subscale, in contrast to children with mild and moderate-to-severe OSA, who had the largest change in the sleep disturbance subscale.

3.4. Linear mixed model analysis

At baseline, preoperative OSA-18 total scores did not differed significantly among gender, age, adiposity, and disease severity

Table 2
The OSA-18 subscale scores before and after surgery in all subjects and subgroups.

Subgroup	*n*	Sleep disturbance (S)			Physical symptoms (P)			Emotional distress (E)			Daytime function (D)			Caregiver concerns (C)		
		Pre	Post	SRM	Pre	Post	SRM	Pre	Post	SRM	Pre	Post	SRM	Pre	Post	SRM
All subjects	144	17.9 ± 5.1	7.3 ± 3.0	2.0	17.0 ± 4.1	8.9 ± 3.3	1.7	8.1 ± 3.7	6.3 ± 3.1	0.5	9.9 ± 4.1	6.6 ± 2.8	0.9	18.1 ± 4.8	11.9 ± 5.4	1.2
Gender																
Male	109	17.9 ± 5.3	7.4 ± 2.8	2.0	17.3 ± 4.2	8.9 ± 3.2	1.8	8.2 ± 3.9	6.3 ± 2.9	0.6	9.6 ± 3.8	6.4 ± 2.4	0.9	18.5 ± 4.6	11.8 ± 5.4	1.3
Female	35	17.7 ± 4.5	7.2 ± 3.6	2.0	16.1 ± 3.8	8.6 ± 3.7	1.6	7.6 ± 3.4	6.2 ± 3.6	0.4	10.9 ± 4.6	7.4 ± 3.8	0.9	17.1 ± 5.4	12.3 ± 5.6	1.0
Age																
<6 years	64	18.1 ± 5.3	7.7 ± 3.1	2.0	17.6 ± 4.4	9.2 ± 2.7	1.8	8.5 ± 3.9	7.0 ± 3.2	0.4	9.4 ± 3.9	6.7 ± 2.7	0.8	18.7 ± 5.3	12.0 ± 5.5	1.3
≥6 years	80	17.7 ± 5.0	7.0 ± 2.8	2.1	16.5 ± 3.9	8.6 ± 3.6	1.7	7.7 ± 3.6	5.7 ± 2.9	0.7	10.4 ± 4.1	6.6 ± 2.9	1.0	17.7 ± 4.4	11.8 ± 5.4	1.1
Adiposity																
Non-obese	117	17.5 ± 5.1	7.0 ± 2.6	2.0	16.9 ± 4.2	8.9 ± 3.4	1.6	8.0 ± 3.6	6.4 ± 3.2	0.5	9.5 ± 3.9	6.4 ± 2.6	0.8	18.1 ± 4.8	11.8 ± 5.6	1.2
Obese	27	19.6 ± 5.0	8.9 ± 3.9	2.3	17.4 ± 3.8	8.9 ± 3.0	2.7	8.4 ± 4.5	5.6 ± 2.6	0.8	12.0 ± 4.3	7.7 ± 3.4	1.1	18.2 ± 4.9	12.4 ± 4.4	1.4
SDB groups																
AHI < 1	16	14.1 ± 4.9	7.2 ± 2.5	1.5	16.8 ± 3.8	9.1 ± 4.4	1.7	8.0 ± 3.1	6.0 ± 3.4	0.7	8.4 ± 3.3	6.3 ± 3.6	0.7	18.8 ± 4.0	12.5 ± 7.0	1.0
1 ≤ AHI < 5	50	17.5 ± 4.4	7.8 ± 3.5	2.0	16.6 ± 3.9	9.2 ± 3.3	1.6	8.0 ± 3.4	6.4 ± 3.1	0.5	9.3 ± 4.2	6.9 ± 2.7	0.6	17.3 ± 4.6	12.3 ± 4.7	1.1
AHI ≥ 5	78	18.9 ± 5.3	7.1 ± 2.7	2.3	17.3 ± 4.4	8.6 ± 3.0	1.8	8.1 ± 4.1	6.2 ± 3.0	0.6	10.7 ± 4.0	6.5 ± 2.7	1.2	18.5 ± 5.1	11.5 ± 5.5	1.3

Note: Data are expressed as mean ±standard deviation; AHI = apnea/hypopnea index; OSA-18 = Obstructive sleep apnea 18-items questionnaire; SDB = sleep-disordered breathing; SRM = standardized response mean, indicating difference score divided by the standard deviation of the difference score. All *P* values of paired-sample *t*-test <0.05.

Table 3
The linear mixed modeling of OSA-18 scores.

Parameters / Outcomes	OSA-18 total score		Sleep disturbance		Physical symptoms		Emotional distress		Daytime function		Caregiver concerns	
	B	*P*	*B*	*P*	*B*	*P*	*B*	*P*	*B*	*P*	*B*	*P*
Intercept	72.2	<0.001	18.6	<0.001	17.0	<0.001	8.0	<0.001	10.7	<0.001	18.2	<0.001
Time (post OP *vs.* pre OP)	−32.1	<0.001	−12.0	<0.001	−8.4	<0.001	−0.8	NS	−3.7	<0.001	−6.5	<0.001
Gender (male *vs.* female)	2.2	NS	0.3	NS	1.1	NS	0.5	NS	−1.1	NS	1.2	NS
Age (≥6 years *vs.* <6 years)	−2.9	NS	−0.6	NS	−1.2	NS	−0.8	NS	0.7	NS	−1.1	NS
Obese (obesity *vs.* non-obese)	5.3	NS	1.6	NS	0.7	NS	0.6	NS	2.0	0.008	0.2	NS
SDB groups												
AHI < 1 *vs.* AHI ≥ 5	−7.4	NS	−4.6	<0.001	−0.5	NS	−0.3	NS	−2.1	0.033	0.2	NS
1 ≤ AHI < 5 *vs.* AHI ≥ 5	−4.2	NS	−1.2	NS	−0.6	NS	0.0	NS	−1.1	NS	−1.2	NS
Time × gender	−2.4	NS	0.1	NS	−0.8	NS	−0.7	NS	0.3	NS	−1.6	NS
Time × age	0.5	NS	−0.2	NS	0.7	NS	−0.4	NS	−0.8	NS	1.0	NS
Time × obese	−0.2	NS	0.7	NS	−0.4	NS	−1.3	NS	−0.6	NS	0.6	NS
Time × SDB groups												
AHI < 1	11.7	0.004[a]	5.1	0.001[a]	1.2	NS	−0.2	NS	2.1	0.039[a]	1.3	NS
1 ≤ AHI < 5	7.7	0.003[a]	2.3	0.012[a]	1.2	NS	0.05	NS	1.7	0.008[a]	2.1	0.021[a]

Note: B = parameter estimates; NS = not significant. AHI = apnea/hypopnea index; OSA-18 = obstructive sleep apnea 18-items questionnaire. SDB = sleep-disordered breathing.
[a] Significant level was below 0.05.

subgroups. Table 3 shows the linear mixed modeling of OSA-18

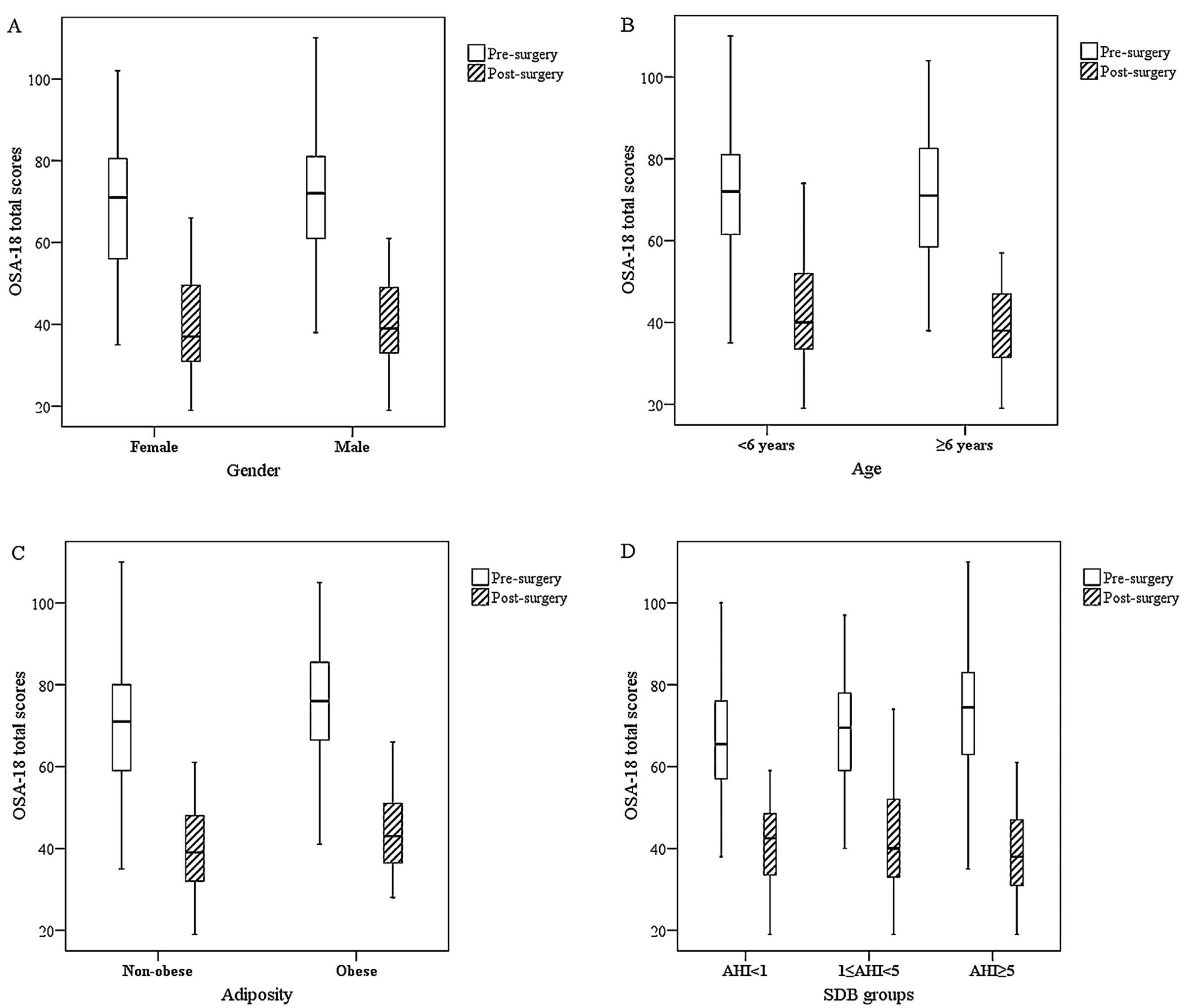

Fig. 1. Comparisons of the OSA-18 total scores before and after surgery in subgroups. (A) gender, (B) age, (C) adiposity, and (D) SDB severity.
Note: OSA-18 = obstructive sleep apnea 18-items questionnaire.
SDB = sleep-disordered breathing
Pre-surgery = pre-surgery survey; Post-surgery = post-surgery survey.

total and subscale scores for subgroups. The linear mixed model analysis indicates that changes in OSA-18 total score did not significantly differ in all subscales for gender, age, and adiposity subgroups, after adjusting for other covariates (Table 3 and Fig. 1A–C). In terms of SDB groups, significant interaction terms (by time) were observed in OSA-18 total score and the three subscales of sleep disturbance, daytime function, and caregiver concerns. The OSA-18 total scores for children with moderate-to-severe OSA, as compared to those with primary snoring children, better improved by 11.7 points ($P = 0.004$) after surgery. Children with moderate-to-severe OSA, as compared to subjects with mild OSA, also had 7.7 points ($P = 0.003$) better improved in the OSA-18 total scores after surgery (Table 3 and Fig. 1D). Further analyses based on subscale scores show that the sleep disturbance subscale, daytime function subscale and caregiver concerns subscale also had significant interaction terms for different SDB groups, indicating that subjects with moderate-to-severe OSA had greater improvements than those with mild OSA or primary snoring children in these three subscales (Table 3).

4. Discussion

This study assessed QoL changes and discrepancies after T&A for children in different subgroups (*i.e.,* gender, age, adiposity and disease severity). The main finding was that children with SDB had a QoL improvement after T&A, despite demographic differences. Particularly, QoL after T&A for SDB children improved more for those with severe obstructive sleep disorders than those with a milder obstructive sleep disorder. From a clinical perspective, those with severe disease should be given priority for treatment due to a greater risk of further co-morbidities, and because of the likelihood of additional QoL gains after surgery.

The main objective of the study is to elucidate changes in QoL for children with SDB underwent T&A. We used the LMM because of its advantages over traditional statistical methods in analyzing repeated-measure data [27–30]. First, LMM can use all available data and allows the existence of missing data, and thus it will not delete all measurements of a subject when he or she has one or more missing measurements. Second, LMM can properly account for correlation between repeated measurements on the same subject if a correct covariance-variance matrix is chosen and it has a greater flexibility to model time effects (*i.e.*, linear slope, quadratic, cubic or more polynomial). Third, LMM can handle both time-dependent (time-varying) covariates, namely the covariates that change with time, and time-independent covariates. Fourth, LMM can incorporate both fixed and random effects. Individual's response at baseline (intercept) is allowed to differ across subjects by releasing the random effect of intercept. Moreover, the change in response over time is also allowed to differ across subjects by releasing the random effect of linear slope. By adding the random effects in the model, LMM provides estimated parameters (fixed effect) as well as individual variability of these parameters around the population trend (random effect). Since there is no missing value and our time scheme is simple (pre-surgery *vs.* post-surgery), the application of LMM in this study offers specialty in modeling random effects and thus results in a more precise parameter estimation than that in traditional methods.

Notably, SDB includes a spectrum of upper airway disorders, ranging from primary snoring to OSA [1,2]. Overnight PSG is widely used as the diagnostic gold standard for pediatric obstructive sleep disorders [2,31]. Based on PSG studies, disease severity is classified as primary snoring ($AHI < 1$), mild OSA ($5 > AHI \geq 1$), and moderate-to-severe OSA ($AHI \geq 5$) [6–9]. While primary snoring in children is usually considered benign and its management remains controversial [32], untreated OSA in children is associated with cardiovascular [33,34], neurocognitive [35,36], and somatic growth consequences [9,21]. Enlarged tonsils and adenoids are the primary causes of childhood obstructive sleep disorders [2], indicating why T&A is widely recognized as the first-line therapy for pediatric OSA [6–10]. Children with OSA had a significantly decreased AHI in PSG studies after surgery [6]. Also, T&A offers progress in cardiovascular outcomes [37,38] and biomarker profiles [39–43]. Teo and Mitchell [37] systemically reviewed relevant studies and asserted that children with OSA had improved cardiovascular outcomes (*i.e.*, blood pressure, echocardiographic findings, and heart rate variability) after T&A. Gozal et al. [39–41] reported altered endothelial dysfunctions and inflammatory profiles after treatment. These findings confirmed that the adverse consequences raised by OSA in children were reversible after treatment, providing evidences of the beneficial effects of early T&A [10].

The impacts of pediatric SDB on QoL have recently received increased attention [12–16,21,44–48]. Measuring QoL involves the use of self- or caregiver-administered instruments that quantify the impact on sleep problems, physical symptoms, emotional state, and family interaction. Both general and disease-specific instruments have been applied to define the impact of pediatric SDB on life quality [12]. Several disease-specific instruments, including the obstructive sleep disorders-6 (OSD-6) [49] and OSA-18 [13] have been administered to children with SDB. Currently, OSA-18 is the most widely used QoL survey for pediatric SDB [12,21,44–47]. Pertinent studies showed that T&A for children with obstructive sleep disorders is associated with marked short-term [14,44–47,50] and long-term [15,16,51,52] improvement in QoL. These surgical QoL gains have been achieved for Caucasians [14–46] and other races [50–55], even with additional nasal or pharyngeal surgeries [56,57]. Nevertheless, QoL changes are not uniform across all five QoL domains [14]. Mitchell et al. [14] and Baldassari et al. [12] cited sleep disturbance as the domain with greatest change. This study concurs with findings in previous studies in which OSA-18 total scores decreased significantly and sleep disturbance was the post-operatively subscale with the greatest change (Table 2), indicating that T&A markedly improved QoL and resolved most sleep disturbances in children with OSA.

Little is known about QoL and its postoperative changes in youth subgroups with sleep disturbances [58–63]. Mitchell and Kelly [58] reported that QoL improved for both children with OSA and mild SDB after surgery. This study also shows that children with SDB had QoL improvements despite their different characteristics. Another notable finding was that children with moderate-to-severe OSA had greater improvement in QoL after surgery than those with mild OSA or primary snoring. Previous studies reported that OSA-18, a disease specific questionnaire, had a positive correlation with SDB severities for children [13,23]. As in this study, children with moderate-to-severe OSA had higher OSA-18 total scores than children with primary snoring or mild OSA before surgery. Interestingly, children with moderate-to severe OSA had lower OSA-18 total scores than those with in primary snoring or mild OSA children after surgery (Fig. 1). Further analyses demonstrates that improvements in OSA-18 total scores, the sleep disturbance subscale, and caregiver concerns subscale after surgery were related to disease severity, indicating that children with a more severe form of the disease had the greatest improvements in these domains. As disease severity increases, caregivers have suffered from greater QoL interferences. Thus, after putting their children through a difficult general anesthetic and painful recovery of surgery, caregivers feel greater QoL gains than whose children only had a milder form of the disease. This finding suggests that children with severe disease should be treated first, due to the great impacts on QoL before surgery and additional QoL gains after surgery.

Childhood obesity has received considerable interest in recent years. It is associated with an increased incidence of various morbidities, including OSA [2,5,9,21]. Mitchell et al. reported that

both obese and normal-weight children had significant improvement in postoperative OSA-18 scores [45,60–62], and asserted that obese children, as compared with non-obese children, had worse QoL before surgery [62], and were more likely to have persistent OSA and poor QoL after T&A [45]. These findings were consistent with findings in this study, as obese children had higher OSA-18 total scores than non-obese ones preoperatively and postoperatively (Table 2). However, changes in OSA-18 scores after surgery did not differ significantly between obese and non-obese ones, implying that both obese and non-obese children had significant QoL gains after treatment.

This study has certain limitations. First, this study did not recruit a control group. Although T&A is the first line and most effective therapy for pediatric SDB [6–9], recent studies suggested that watchful waiting may also be a reasonable treatment option and result in certain degree of QoL improvement as well [10,64]. Second, this study was conducted in a single, tertiary referral medical center. Therefore, cross-cultural comparisons and racial differences in QoL measures were not obtained. Third, although LMM analysis can get more precise parameter estimation over traditional methods, the problem of small number in some subgroups (*e.g.*, obese *vs.* non-obese) remain unsolved and require future study. Fourth, no long term data were acquired. These limitations warrant the need of large, cross-cultural, long-term follow-up cohort with control group to further elucidate QoL changes after surgery in children with OSA.

5. Conclusions

Children with SDB had QoL improvement after T&A, as documented by OSA-18 score changes. Changes in QoL after surgery did not differ significantly among gender, age, or adiposity subgroups. Nevertheless, QoL after surgery improved more for children with more severe than with milder forms of the disease. Findings provide evidence of QoL gains after surgery for children with SDB, especially for those with more severe forms of obstructive sleep disorders.

Conflicts of interest

The authors declare no conflicts of interest.

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